Teaching and Assessing Complex Skills in Simulation With Application to Rifle Marksmanship Training

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ABSTRACT

This paper summarizes the background, methodology and findings of initial efforts to improve our approach to training and assessing high-performance skills. High performance skills are those that require accurate and precise perceptual – motor coordination to achieve desired levels of expertise. We review and integrate key areas of knowledge related to skill acquisition and expertise, address strategies for teaching and assessing complex skills, and examine the use of technologies that enable precise recording of trainee performance. Instructional strategies are discussed that are designed to accelerate complex skill development, based upon learning principles and enhanced performance feedback. Our emphasis is on teaching the "warrior" skills needed for military serviceman now engaged in very different and challenging war-fighting tasks. Developments in simulation training technologies, with performance monitoring capabilities, provide a means for studying and improving high performance skills. The US Army's Engagement Skills Trainer (EST) was designed to teach basic and advanced marksmanship skills, and can be used to monitor performance progress from novice to expert. In this paper, the EST was used as a test bed to explore possible training enhancements and performance assessment metrics for military rifle marksmanship training. Our study of marksmanship skill benefited from the emergence of precise instrumentation for digital recording of trainee performance. We used motion capture technology to define and to measure proper rifle shooting postural profiles associated with different levels of marksmanship expertise. Motion capture allowed us to model various levels of expertise, ranging from novice to expert, as a means to define skill differences. While results reported here are promising, further research and development in motion capture is needed in order to realize the full potential for the practical application of shooting profiles in the determination of skill levels and analysis of learner deficiencies during simulation training.

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INTRODUCTION

Emerging virtual environment (VE) training technologies provide individual and team training in highly realistic "immersive" environments. In spite of advanced technologies such as the use of high-resolution 3-D displays to depict realistic combat scenes and other technology advances, questions remain about the effectiveness and proper utilization of simulation training. This is the first of a planned series of papers whose purpose is to explore methods for improving the effectiveness of simulation training. It is hoped that this goal will be achieved by applying instructional science, in conjunction with new technologies that enable accurate and precise digital recordings of human performance. This paper focuses on individual performance skills that require complex perceptual motor activity. Examples include certain sports, such as golf and tennis and as studied here, the movement patterns associated with rifle marksmanship. Later papers are planned that will address tactical decision-making and team performance skills.

The paper covers key topics related to the effective training of high-performance skills. It includes a brief overview of selected skill acquisition theory, and recommended instructional strategies for teaching complex skills. The paper then summarizes research designed to test the application of motion capture as a means to model correct rifle marksmanship postures and movement patterns.

COMPLEX SKILL LEARNING ACQUISTION

During the course of learning most complex skills, learners appear to progress through distinct stages. Paul Fitts (1962) was one of the first skill researchers to postulate several phases of complex skill learning that he called (1) *Cognitive* Phase, (2) *Fixation* Phase, and (3) *Autonomous* Phase. During the c*ognitive* phase learner's attempt to verbalize, think about, or "intellectualize", the basic rules and strategies of the skill, and seek to establish some knowledge about the tasks to be performed. During the *fixation* phase, the learner attempts to correct errors and begins to focus, or fixate on the most appropriate response patterns for accurate task performance. The final *autonomous* phase is characterized by a considerable improvement in timing and movement coordination, and faster and more accurate performance. As practice continues there is increased "automaticity", greater resistance to distractions, and a shift from dependence upon external cues to internal (proprioceptive) stimuli as a means to guide coordinated task performance (Fitts, 1962).

During later refinement of the learning stage model, Fitts and Posner (1967) changed the term *fixation* to the term *associative*. The term *associative* just happens to be one that is easily incorporated into the language of contemporary cognitive learning theories.

Learning phase models also were proposed for the *cognitive learning domain*. For example, Anderson (1983) formulated a three stage-learning model based on a learning progression from *declarative knowledge* (represented by propositional networks) to procedural *knowledge* (represented by production rules).

The stages of learning proposed by Anderson are:

- <u>Declarative.</u> The learner receives facts, information, background knowledge, and general instruction about a subject matter or skill. Mental elaboration and [mental] rehearsal at this stage helps to keep information presented in working memory.

- Knowledge Compilation. Practice causes basic knowledge about a skill to convert gradually from declarative form into appropriate new procedures that can be applied directly to the processing of inputs without constant attention.

- Procedural. After declarative knowledge is compiled into a production system, practice refines and strengthens appropriate procedures. Responses show better discrimination and generalization, and become automatized.

The phased progression of learning into distinct stages by Fitts (perceptual-motor learning) and by Anderson (cognitive learning), strongly implies that the typical learner transitions from a state of *knowledge about* a subject or skill, to a state of *rule application*, and finally the learner progresses to a level of *automaticity* or skilled task performance that is executed with minimum conscious monitoring or interruption.

This concept of phased skill development has important implications for the delivery and assessment of instruction for both cognitive learning and complex perceptual-motor learning. Ross, Phillips and Klein (2005) describe another *cognitive* learning stage model that was originally proposed by Dreyfus and Dreyfus (2005). This model is briefly summarized as follows:

1. *Novice* – a novice is one with no prior experience in the learning domain. Novices demonstrate relatively inflexible performance because they are typically relying on "textbook" rules and memorized procedures.
2. *Advanced Beginner* – has acquired some domain experience and is now able to perform more competently, but he/she is still dependent upon rules.
3. *Competent* – the learner has acquired enough knowledge and skill to formulate a strategy to perform on his/her own without reference to rules, but based on experience about what does/does not work.
4. *Proficient* – the individual who has attained "proficiency" can perform to some required standard of acceptance under conditions expected. By now, the core principles of a domain are learned and the performer can perceive recurring patterns and instances gained from experience.
5. *Expert* – the expert no longer relies on memorized rules or guidelines. By now the learner has evolved unique strategies and can perform complex tasks with greater speed and accuracy.

Ross, et al (2005) created a comprehensive set of training guidelines for the cognitive domain primarily for tactical decision making based on the Dreyfus five-stage model. Some instructional strategies suggested are presented below:

Novice: Give learners the rules needed to guide performance, provide direct coaching and close mentoring on tasks and strategies.

Advanced Beginner: Emphasize experiential learning through scenarios designed to illustrate recurring patterns and instances requiring the learner to formulate his/her own strategies and task performance guidelines.

Competent: Increase complexity and variety of task performance conditions and full mission scenarios to include higher-level planning and decision making.

Proficient: Require learner to formulate and test probable solutions given exposure to novel situations. Increase mission/task complexity and time pressure.

Expert: Insert lessons from real-world case history and operational experience. Train with and against other expert level performers. Conduct peer evaluations and feedback (Ross, et al pp. 67-11).

Other researchers studying complex human skills agree that instructional strategies must adjust to the learner's state of learning, or learning phase. For example, Schneider and Schiffrin, (1977), stress the importance of different practice strategies for *controlled processing* and for *automatic processing* modes of skilled performance. When a learner is in early learning stages, and exhibiting primarily controlled processing (consciously monitoring their own performance), the instructional strategy would be to provide practice on a wide variety of conditions. When learners have reached the automatic processing level (unconscious execution) then they should be presented with *consistent task elements* repeated over many practice trials.

Another interesting finding from the study of many different kinds of expertise shows that it takes approximately 10 years to acquire the high level of skill exhibited by an Expert -- they have spent a lot of time practicing. For example, Slobda, Howe and Moore (1996) showed that the major difference between the average skilled musician and the virtuoso (expert) was the amount of time that they practiced.

The experts spent the most time in "solitary practice", accumulating over 10,000 hours by the time they were 20 years old, compared to 2000 hours for amateurs. Studies of expertise have led to the conclusion that it is only through "deliberate practice" over many years (10-year rule) that such high levels of expertise are attained through much focused practice on critical task components, referred to as "deliberate practice" (Ericson, Prictula and Cokeley, 2007).

Deliberate Practice refers to practice that includes not only focusing on what you have learned to do well, but also depends on what you need to do to improve performance in areas that may be deficient. It implies careful and sustained practice – often with good coaching, with rich feedback to improve performance. A good coach "challenges" the emerging expert by identifying components of task practice needed for the trainee to reach the next level of skilled performance. In other words, in order to achieve the high levels of expertise attained by champions, one must practice elements of the task that one "may not be performing well" (Ericsson, Prietula, and Cokely, 2007). In fact, studies of flight simulation training conducted by the US Air Force (McKinney & Davis, 2003) showed clearly that simulation training alone did not improve performance on training emergency situations, unless the learner focused on deliberately practicing key task components.

Ackerman (2007) provided a recent update on "deliberate practice" of complex skills and achieving expert performance. For such skills as steering a car, and for professional sports like baseball, tennis and golf, the skill is composed of tasks that can be taught individually because there are consistent stimuli – response components. For more complex tasks where the responses may vary widely depending upon rapid changes in the situation and environment, success depends more on the expert having a substantial domain knowledge (declarative information) that can be used to sort priorities and to logically derive solution strategies, prior to responding**.**

Finally, mention should be made about some cognitive principles of teaching, exemplified by the "Constructionist" view of instruction. From the constructionist view point, the most effective learning takes place by engaging learners to solve real-world problems, and to demonstrate skills under instruction in real or simulated problem solving situations. Much of the constructionist movement is dedicated to education and is not specifically focused on teaching complex perceptual motor skills. Some instructional scientists have used constructionist ideas to recommend strategies for improving any form of instruction.

For example, Merrill (2002) considered the key ideas underlying the constructionist view in his review of instructional science principles. By way of summary Merrill suggests that *instruction is most effective,* if the following principles are followed:

- *Task Centered Principle* – focus on real-world tasks but break instruction into meaningful part and whole task segments.

- *Activation Principle* – relate new learning to what the learner already has been taught.

- *Demonstration Principle* – learners must be able to observe required performance and be given guidance on task requirements.

- *Application Principle* – learners should be given an opportunity to use or apply their newly learned task (practice with feedback).

- *Integration Principle* – learners are encouraged to use new learning in the context of other tasks in the real world.

The above teaching recommendations are of interest to our line of research and will be considered during the course of our research regarding improvements to marksmanship simulation training. But here, we are **especially interested in applying enhanced feedback** to the learner during critical phases of skill acquisition.

One means of improving feedback would be to use recorded measures of performance to correct skill deficiencies. Later in this paper, we will propose the use of motion capture movement profiles as a means for trainees to visualize the correct postural position of an expert marksman. The use of such methods as digital motion capture may help the instructor to demonstrate correct movement and positional performance, and to assess the state of skill development following a training session. In general, we are suggesting that it would be very valuable for the learner to observe a visual representation of the correct position and movement pattern for skills requiring precise postural position and coordinated movement patterns. Later in the paper, we will illustrate how motion capture (with digital imaging) can potentially serve the purpose of providing a reliable means for instructors to demonstrate correct positioning of a shooter, and to

assess correct rifle shooting coordination and movement stability required for accurate shooting.

Simulation Training And Complex Skills

Findings from Skilled performance can be applied to improve the effectiveness of simulation training.
For example, it appears most beneficial to offer cognitive approaches early in training, and then shift to perceptual-motor aiding later in the training period. Also, instructional designers should identify context (environmental) cues that are the most powerful in capturing attention and initiating correct or incorrect responses during later periods of training. Instructional designers should attempt to identify cognitive and perceptual- motor components of a complex skill in order to develop effective instructional strategies.

Since the composition of the skill itself appears to change over time, then it would seem that the conditions of learning and the training strategy must change as well. Most of the skill literature supports the idea of laying a strong knowledge foundation for learners of complex skills, prior to hands–on practice. Like a good coach, the instructor shares his/her knowledge about key facts, correct task procedure, relevant sensory cues and other factors. For later practice sessions, minimum coaching is used such that the learner can focus on deliberately practicing key task performance components. Often, deliberate practice entails demonstrating "part–task" skill components during simulation trials in which proficiency on subtasks is taught prior to moving to final skill integration or whole task practice.

Here is a summary of recommended instructional strategies:

Teaching Strategies for Cognitive Phase

1. Provide students with tutorial information regarding the task structure and salient cues to pay attention to during task performance.
2. Learner should be given a relevant organizational introduction to the task domain prior to engaging in practice trials.
3. Demonstrate correct performance showing correct response sequence and timing.
4. Reinforce attention to salient cues during practice sessions, and provide diagnostic feedback of performance results.
5. As skill becomes more automated, provide less coaching and verbal support during practice.
6. Provide cognitive information and/or verbal feedback during practice. But for trainees who have reached the level of skill automaticity, verbal feedback may interfere with learning.
7. It may be most beneficial to offer cognitive approaches to skill learning early in training, and then shift to perceptual-motor aiding later in the training period.

Teaching Strategies for Associative Phase

1. Provide the learner an opportunity to practice the procedure (with coaching and feedback).
2. Test student at completion of practice trials at appropriate level of performance defined in the learning objectives.
3. Complex tasks can be broken down into key components for deliberate practice.

Teaching Strategies for the Autonomous Phase

1. Continue deliberate practice on the more difficult task components.
2. Increase the speed of response and task difficulty progression. (Challenge the learner.)

By way of summary, we have suggested a variety of "instructional strategies" that might improve the quality and effectiveness of training perceptual-motor skills.
We have recommended laying a solid knowledge foundation of a skill (the facts, the concepts, the procedures, and success strategies) associated with skilled performance in a given domain (whether sports or marksmanship skills) during the *cognitive phase* of learning and then during later learning phases (*Associative* and *Autonomous)* one must relax verbal coaching and provide opportunities for deliberate practice on more difficult task elements.

Having a record of learner performance, serves as a means to show correct and incorrect performances. Simulators often provide some form of final scores.
Such scores, however, seldom provide the level of diagnostic detail for a learner to model and to adjust his/her performance needed to meet a desired standard.

ASSESSING COMPLEX SKILLS

Clearly, one critical aspect of skill training is to provide performance assessment as corrective feedback, and a means to determine skill proficiency. Listed below are various forms of assessment for both cognitive and perceptual motor skill components.

Cognitive – recall knowledge factors

- Exams – written or oral recall
- Laboratory exams (skill demonstration)
- Simulation and game exercises
- Problem solving projects (teamwork)

Perceptual – Motor – perform tasks

- Response or reaction times
- Response rates (frequency or percent)
- Accuracy (mean, median, mode)
- Precision (performance variation)
- Errors and deviations from a criterion or norm

Performance measures available from simulation, like the US Army Engagement Skills Trainer 2000 (EST 2000), provide scoring metrics that show final shooting score accuracy and precision. This scoring information (Illustrated in Figure 1) may be useful in estimating a given level of accuracy. But this outcome scoring does not provide diagnostic feedback to correct skill deficiencies.

Figure 1: EST Scoring - target shot pattern

Rifle Marksmanship Research

A substantial amount of research has been conducted previously to study the acquisition of marksmanship skills. These studies helped shed light on the nature of the skill and also identified strategies for success.

For a comprehensive literature review and analysis of marksmanship training literature see Baker (2004). An important recommendation made in this study of rifle marksmanship was that “marksmanship research should be framed within a *phases of skill development* such as Fitt’s (1962) three-stage skill acquisition model. Chung, Delecruz, De Vries, Bewley and Baker (2006), in their study of marksmanship skills conclude that rifle sight alignment, aiming, stock weld, breath control and trigger control remain important in spite of advancements in weapon sight technology.

Other marksmanship studies have attempted to demonstrate a relationship between simulation training and live fire exercise practice, but have met with varying levels of success. Hughes and Nau (2007) studied the capability of the Army’s Engagement Skills Trainer to serve as a substitute for live fire training of certain heavy weapons (Browning machine gun and other high caliber weapons). The study compared soldiers who trained with the EST 2000 to those who trained exclusively on the live fire range. Both trainees and instructors completed a survey that evaluated the strengths and weaknesses of each training method. The study concluded that the EST could help maintain skills in the absence of an opportunity to train on a live fire range.

A number of other studies have demonstrated a positive training transfer between rifle marksmanship simulators and live fire ranges. For example, Smith and Hagman (2000) conducted a study to demonstrate utilization of the US Army’s Laser Marksmanship Trainer (LMTS) for teaching basic marksmanship skills (stock weld, aiming, breath control, and trigger squeeze). The study included training on the LMTS and development of regression equations that were successful in predicting success during later rifle range qualification tests. However, the equations were not useful for determining the specific level of skill and specific skill qualification differences (i.e. marksman, sharpshooter, and expert). The primary use of the regression model was to determine the need for remedial training.

In another training transfer study, Yates (2004) was unable to establish a reliable transfer from the simulator (Indoor Simulated Marksmanship Trainer) to live fire shooting, probably due to windy weather conditions. Wind and rain led to lower scores for many shooters performing on the rifle live fire range transfer tests.

RIFLE MARKSMANSHIP APPLICATION

Research Objective

The literature reviewed here suggests many areas of potentially fruitful research, but for our purposes we decided to focus on studying movement behavior related to rifle marksmanship training. The authors believed that providing instructors and trainees with a precisely recorded digital representation of correct postural position and movement pattern would serve to demonstrate the correct shooting position and would provide feedback on positional errors. Shooting positions are defined and illustrated in military shooting manuals (USMC 2001). Figure 2 shows an example of the correct "prone firing position."

Figure 2: Example of Correct Prone Position

The applied experimental research used the EST 2000 as a test bed to explore the use of instructional enhancements based on recent studies of complex skill acquisition and expertise. This study of marksmanship skill benefited from the emergence of highly precise instrumentation for digital recording of trainee performance. We used video *motion capture technology* to define and to measure rifle shooting postural profiles associated with different levels of marksmanship expertise. Our approach focused on modeling various levels of expertise, running from novice to expert, as a means to define marksmanship skill differences. It was hoped that this approach would provide a potential means to illustrate correct rifle-shooting postures, and to provide diagnostic feedback to trainees for correcting shooting skill deficiencies.

We wanted to give a Drill Sergeant or marksmanship instructor a method to provide the most useful feedback. All drill sergeants are taught good training techniques and procedures, but by no means are they perfect judges, or free of personal bias.

If one could create a "virtual soldier" computer model that could demonstrate the standard of the proper body posture while firing, this would help to alleviate inconsistencies in marksmanship training.

From the moment the Soldier arrives at basic training he/she could immediately visualize, via digital image rendering, what the recommended standard body posture should be for various shooter positions (Platt & Powers, 2008).

Marksmanship Fundamentals

The characteristics of marksmanship are those key fundamentals that are considered critical to engaging a target with an accurate shot from a rifle. Each of the characteristics is defined by the military marksmanship manuals of the U.S. Army and United States Marine Corps (See US Army FM 3-22.9 Rifle Marksmanship, 2008, for example). Baker (2004) summarized correct shooting procedures in a comprehensive task analysis. Briefly, the main fundamentals of marksmanship are aiming, stock weld, breath control, trigger control, and recoil recovery. These fundamentals and their associated assessment metrics are outlined below:

Marksmanship Instruction Fundamentals

- Aiming – includes aligning the rifle sight and achieving the proper sight picture (placing the target in the sight crosshair)
- Stock weld (keeping the rifle firmly between cheek and stock of rifle)
- Breath and Trigger Control (controlling breath as to not move rifle position, while gently squeezing and not jerking at trigger pull)

Marksmanship Assessment fundamentals: Cognitive

- Explain concept of firing accuracy (gun sight alignment, aiming, breath and trigger control)
- Define sight alignment and sight picture
- Using rifle, show instructor correct aiming and hold the rifle in proper stock weld

Marksmanship Assessment: Perceptual Motor

- Accuracy and precision scores from EST (target hits/kills and shot pattern variance)
- Trigger pressure value (from EST)
- Rifle butt pressure value (from EST)
- Rifle cant position value (from EST)
- Breathing control (instructor observation)

Movement – Motion Capture

Motion Capture, or "MOCAP", involves measuring a person's position and orientation in physical space, then digitally recording that information for detailed computer analysis of movement performance (Dyer, Martin, & Zulauf, 1995).

Motion Capture Equipment

The Vicon, Inc. T60 Motion Capture Camera system was used to collect all motion capture data used in this study. The cameras have a resolution of 0.3 megapixels and capture speeds of up to 200 frames per second.

Motion Capture Procedure

The steps required to set up and operate a motion capture sequence include: (1) studio arrangement and camera set up, (2) calibration of capture area, (3) capture of movement performance, (4) clean up and post – processing of data (2-D or 3-D rendering).
In full body motion capture, markers are placed at selected points on the performer's body. The performer wears reflective markers that are followed by the high-resolution cameras and the information is triangulated among cameras. The process of subject calibration modifies a template skeleton so that it closely matches the subject's anthropometric measurements. The calibrated skeleton can then be used to evaluate the motion capture data, fill data gaps and reconstruct the actual movement performance (Dyer, Martin and Zulauf, 1995).

SANTOS™

Santos™ is a comprehensive computer human model, developed by the Virtual Soldier Research Program (VSR) at the University of Iowa that simulates the movement of the complete human body and provides detailed feedback for analysis. Santos™ provides predictive capabilities, meaning posture and motion are not simulated using pre-recorded data; they are simulated using validated mathematical models that can be re-run easily with changes in problem parameters. Consequently, Santos™ actually predicts how people strike various poses and how they move. With this approach used for motion prediction, Santos™ allows the user to study what drives human motion. That is, one can see the results of having a virtual human move as if he/she is minimizing different performance parameters like energy, cumulative joint torque, and joint displacement, etc. We used the physics- based inverse kinematics capability of Santos. In this case, motion capture data was imported to Santos and Santos solved for various body joints. The result of this process is an animation file for Santos. Based on this data, Santos can predict several performance outcomes such as limb positional discomfort and fatigue.

Marksmanship Training Application

If we apply the instructional principles discussed earlier to marksmanship training we would begin instruction by teaching some of the important "cognitive" aspects of the skill first. In live fire and simulation training, the instructor would brief basic procedures, such as stock weld, and other basic procedures shown in Table 1, below. Emerging interactive virtual reality technology may be of substantial benefit in teaching the basics, via a computer based tutorial that could be followed by a detailed visual demonstration (animation), using a kinematic "virtual soldier" model like that produced by SANTOS™.

Table 1: Marksmanship Instructional Strategies

Marksmanship Task	**Teach**	**Demonstrate (Instructor)**	**Assess (Student)**
Hold steady Stock Weld	Tell how	Show how Or illustrate	Tell how Show how
Control Weapon Cant	Tell how	Show how Or illustrate	Tell how Show how
Sight/Aim rifle	Tell how	Show how Or illustrate	Tell how Show how
Control breath & trigger pull	Tell how	Show how Or illustrate	Tell how Show how

Motion Capture Demonstration

A Motion capture demonstration was conducted at the University of Iowa, using the Vicon Camera set up (described earlier), while 18 volunteer subjects participated in firing the EST simulated MA16A2. Twelve cameras were calibrated in accordance with Vicon "wand" calibration procedures described in detail in Platt and Powers (2008). Subjects received 18 rounds to "zero" their rifle. Zeroing the rifle required the shooter to place the weapon in the correct line of sight, point of aim to the center rifle bore, and to make any adjustments necessary to steady the rifle for correct aiming.

For the MA16A2 Rifle used here, the shooter had to zero the weapon by firing a certain number of shots within a 4-centimeter circle. If subjects could not properly zero their weapon, they were disqualified and did not participate further. Each Subject was escorted to the EST 2000 simulator in which the motion - capture system was positioned in a 360-degree coverage (Figure 3 & 4). Motion capture data was taken for 17 of the subjects who qualified, but because of time constraints only four subjects could be rendered into SANTOS.

Figure 3: EST Training Session Set up

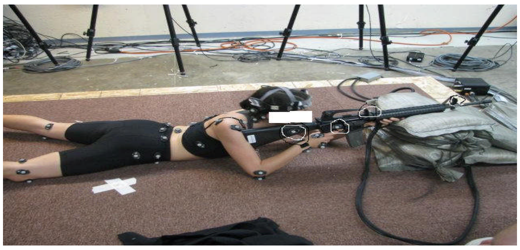
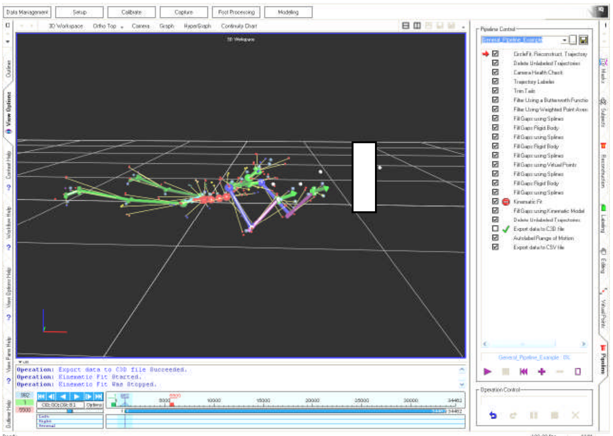


Figure 4 EST MOCAP Set up

RESULTS AND DISCUSSION

The four subjects were selected to represent different skill levels (Expert – 40/40 successful shots; "Marksman" 31/40 successful shots, one who was the "Unqualified" or a "poor" performer 0/18, and another, a "trainee" who received some coaching and was allowed to observe ongoing training sessions. Post processing of the motion capture was needed in order to incorporate areas of the body not fully traced during the recording session (Figure 5).

Figure 5: SANTOS™ MOCAP Post Processing



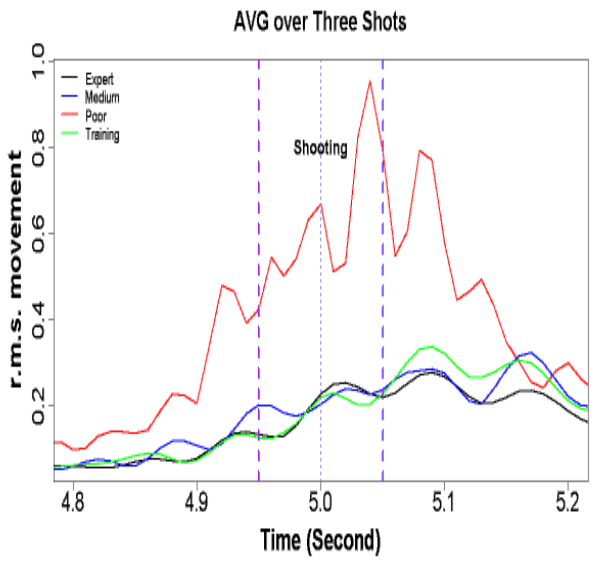
Each subject's movement pattern was recorded during the rifle firing sequence over a 4.8-5.2 second shot interval, representing the *ready, aim, fire* and *recoil* recovery period. All movement was measured from the previous location of a marker in relation to its new position. These new positions were rendered frame by frame so that movement was measured by one one-hundredth of a second. Very small degrees of movement were recorded using this method, thereby allowing visual depiction of the subject's performance (Platt and Powers, 2008). The root mean squared (RMS) movement of all the joint center locations ti +1(marker XYZ position change) was then calculated using this formula for movement RMS:

$$\text{RMS} = \sqrt{(x_{t_i} - x_{t_{i+1}})^2 + (y_{t_i} - y_{t_{i+1}})^2 + (z_{t_i} - z_{t_{i+1}})^2}$$

Figure 6 shows the movement (RMS) results obtained for the four subjects selected for analysis. As can be seen, RMS error is clearly higher for the poorest performer, whereas differences are harder to distinguish among the Expert, Marksman and Trainee shooters.

Clearly, these results from this exploratory research are limited at this point, but the authors believe that with further refinement and improved MOCAP technology there is a strong likelihood that we will be able to model and interpret skilled movement performance. One can imagine the possibility of creating postural profiles that depict correct shooting position, based upon recording the postures and movement pattern of expert marksman.

Figure 6: MOCAP Movement RMS Profiles



Additional research is planned to evaluate the potential of motion capture profiles. We also will investigate variations in the science – based instructional strategies for basic marksmanship simulation training. In doing so, we plan to take advantage of available performance measurement simulation recordings and supplemental digital recording technologies of motion patterns. With further refinement, these methods may prove useful in assessing different levels of proficiency and may help illustrate marksmanship fundamentals.

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